

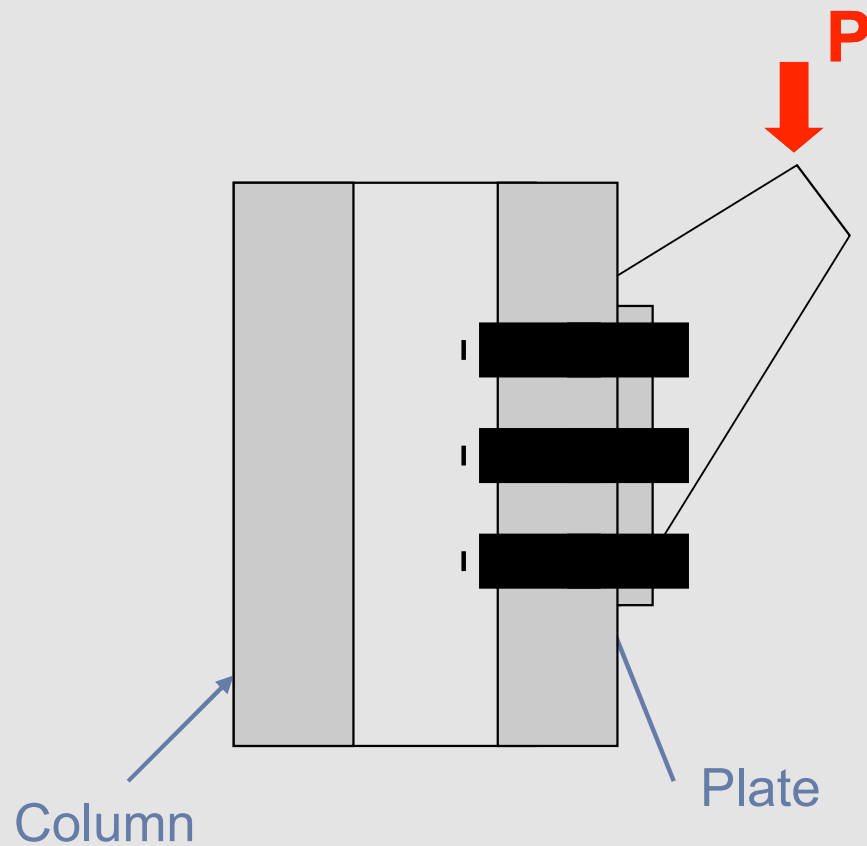
C & EE 141

Eccentric Connections

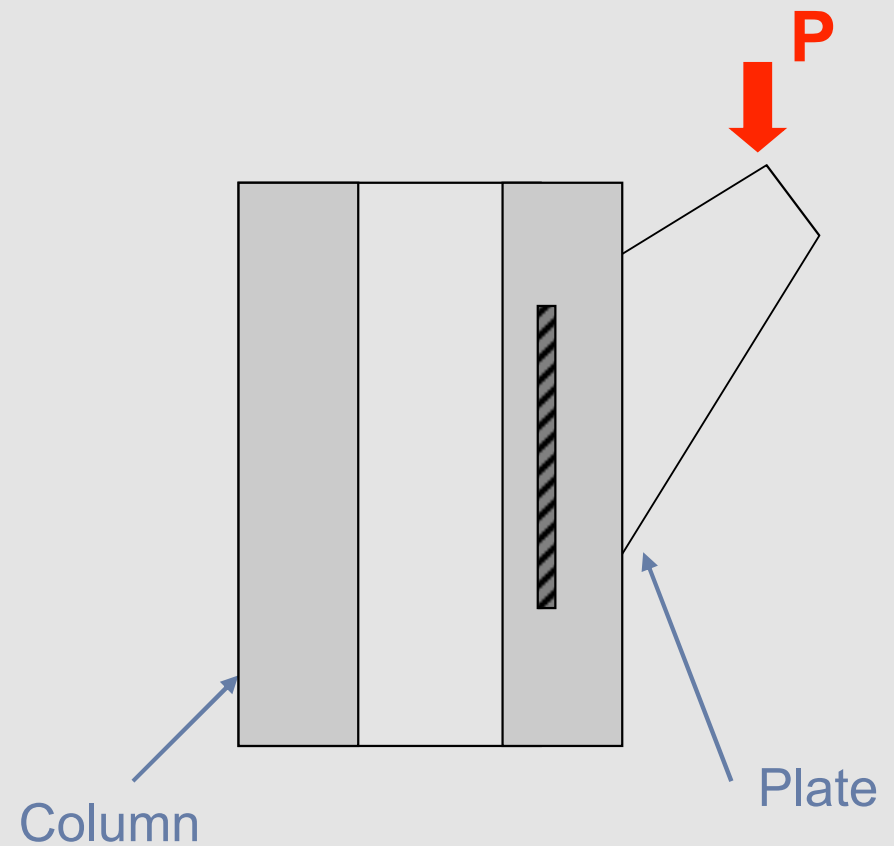
Suggested Reading

- AISC SCM, Section 7
 - Pg. 7-6 to 7-9 (Elastic Method only)
 - Pg. 7-10 to 7-13 (Case II assumption only)
- AISC SCM, Section 8
 - Pg. 8-9, 8-12 to 8-15 (Elastic Method only)
- Reference on CCLE

Eccentric Connections



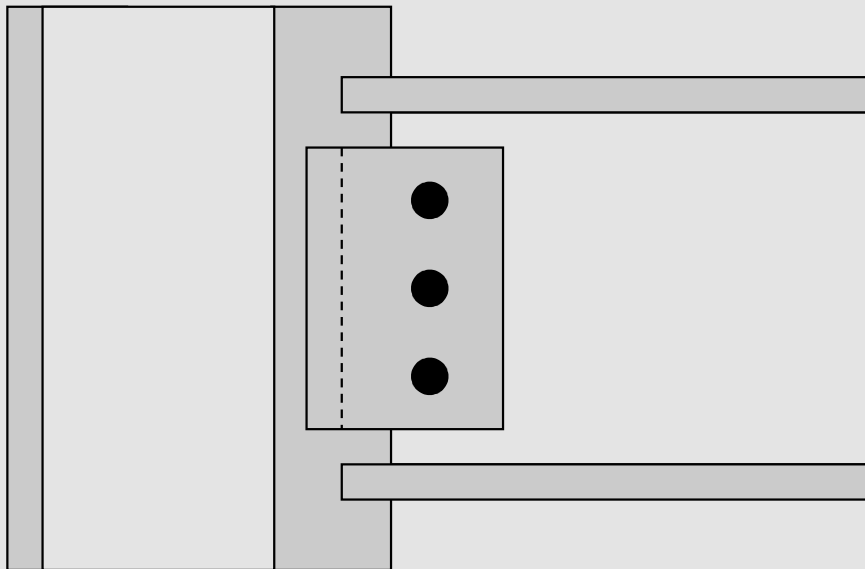
BOLTS



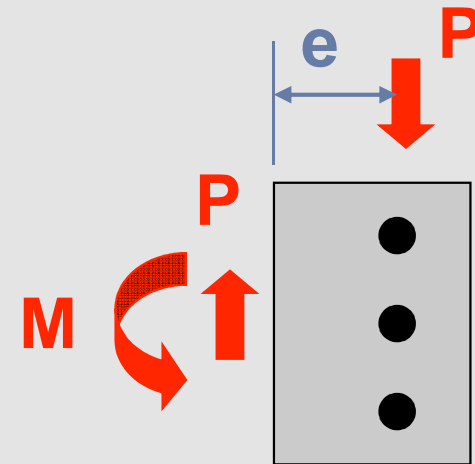
WELDS

Eccentric Connections

- Occur when the resultant of the applied load does not pass through the C.G. of the connection
- Most connections have some eccentricity



Typ Beam to Column Conn.



FBD of Plate

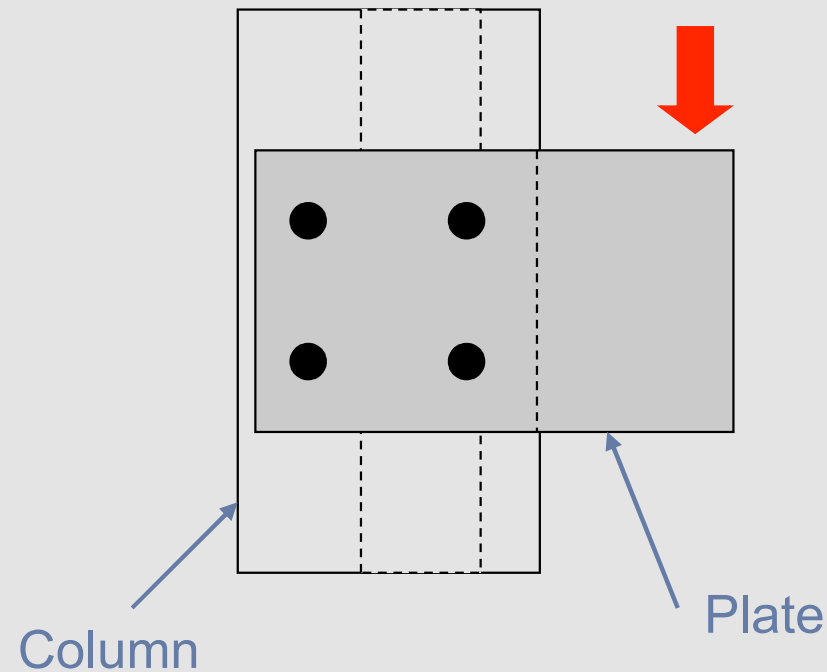
Eccentric Bolted Connections

Bolt Analysis Methods

- Elastic Method
 - Conservative approach
 - Historically used & most commonly used approach
 - Friction between parts ignored
 - Bolts are considered rigid (no deformation)
- Instantaneous Center of Rotation Method
 - Considers deformation at each bolt
 - Better match to actual test results
 - Very tedious to apply
 - Tables in manual may be used (but only if bolt pattern is a match)

We will focus on the Elastic Method only

Eccentricity in Plane of Faying Surface

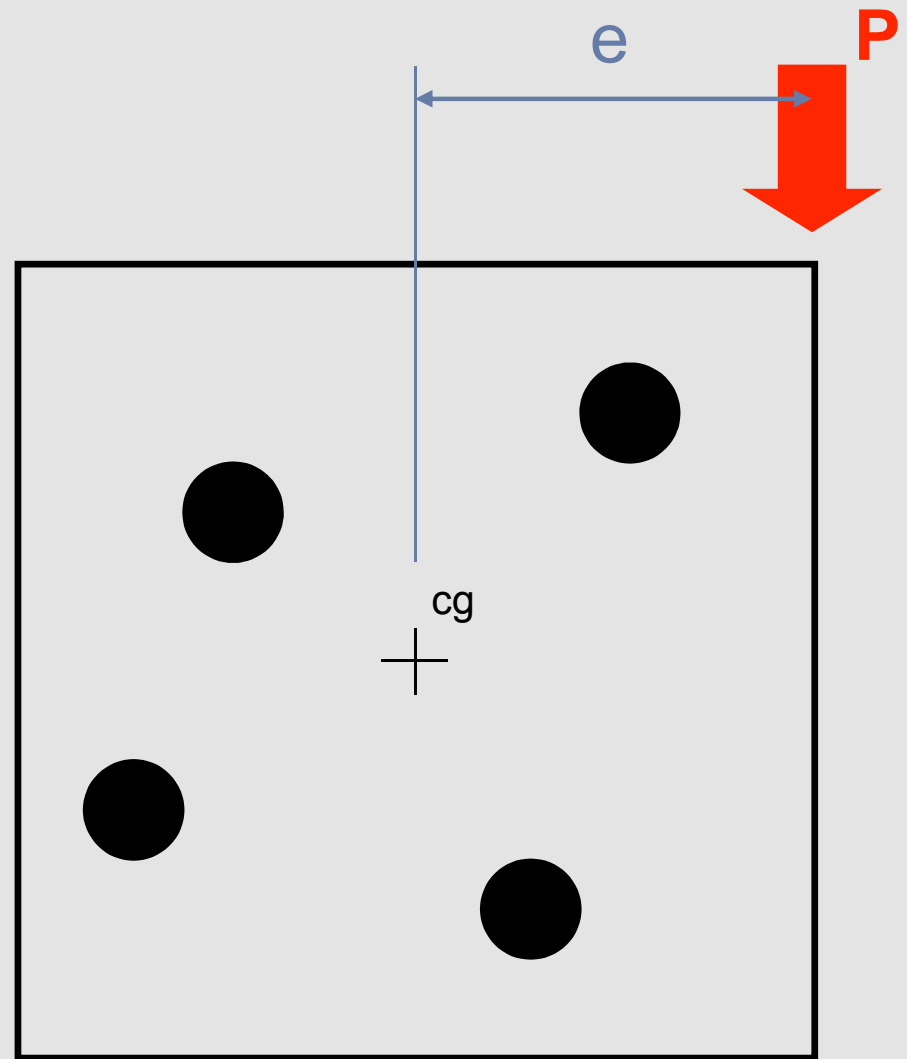


BOLTS

Elastic Method

(Ecc. in Plane of Faying Surface)

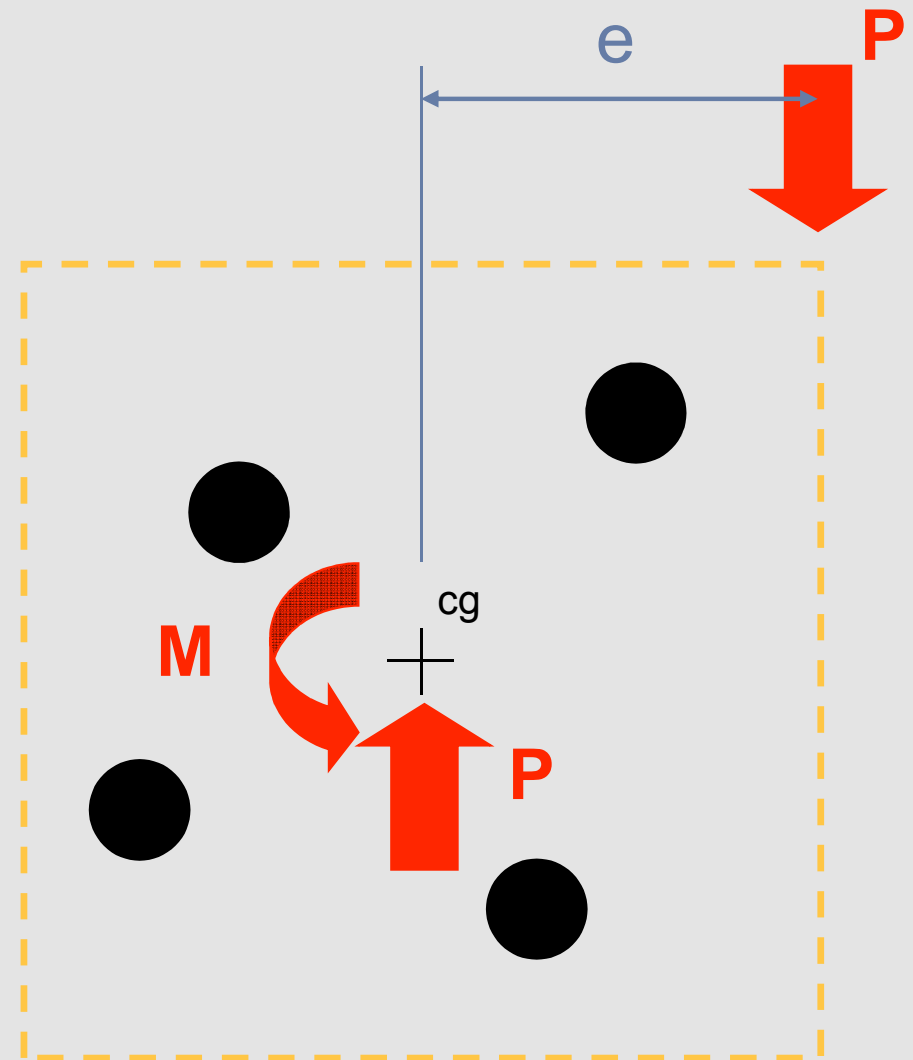
- Force is applied offset from the C.G. of the bolt group.
 - Eccentricity is in the plane of the faying surface



Elastic Method

(Ecc. in Plane of Faying Surface)

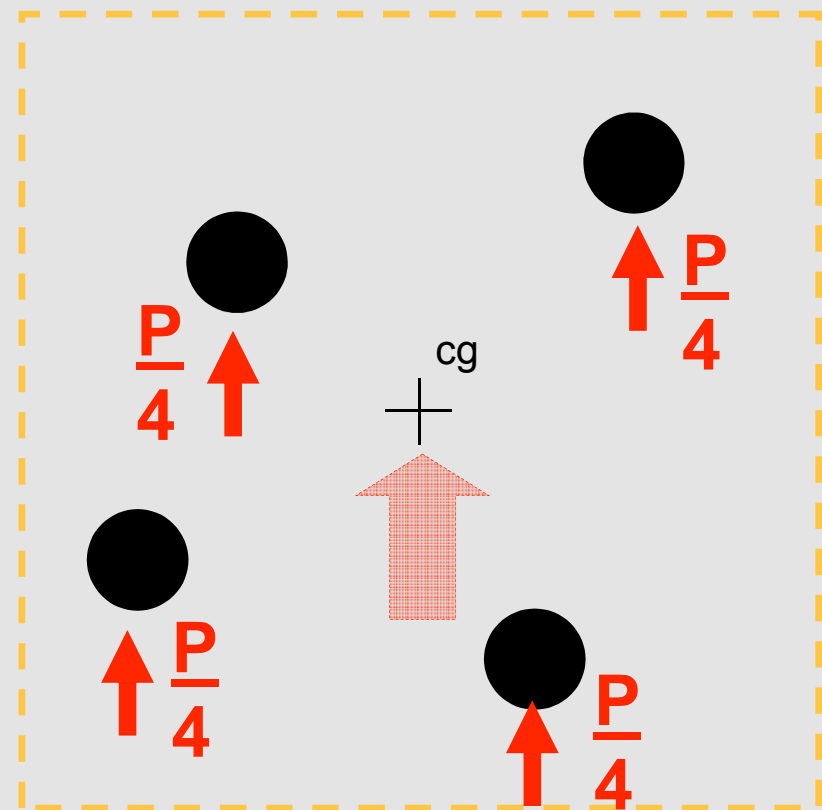
- Equivalent force-couple occurs at C.G. of bolt group



Elastic Method

(Ecc. in Plane of Faying Surface)

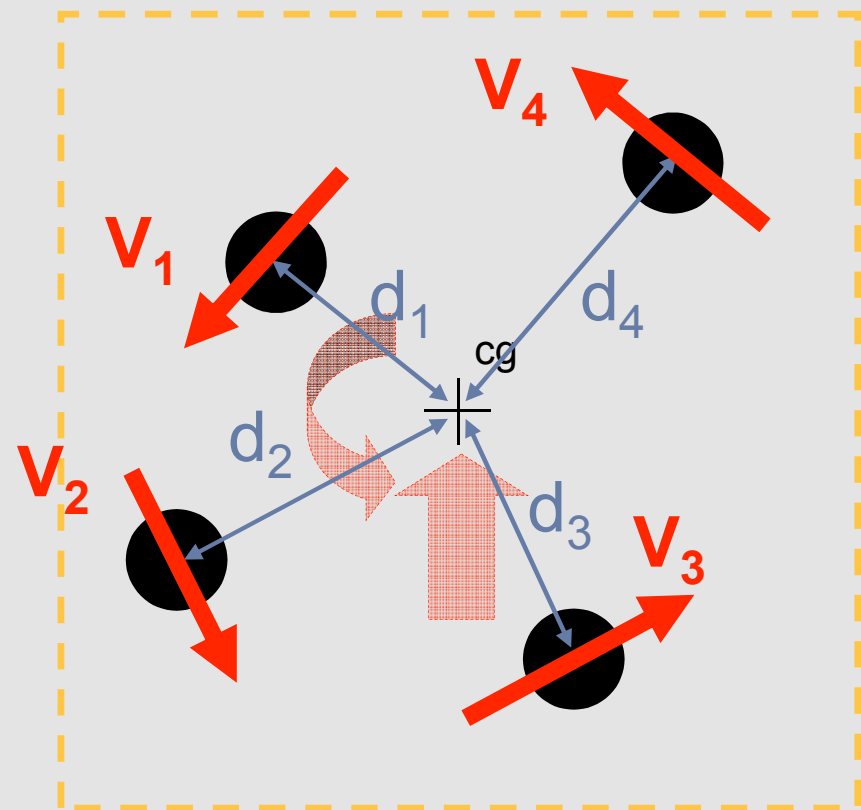
- Direct shear is shared equally by each of the bolts



Elastic Method

(Ecc. in Plane of Faying Surface)

- Moment is resisted by shear in each bolt in proportion to each bolt's distance from the C.G.
- Shear due to moment is normal to radial vector from C.G.
- $M = \sum V_i d_i$



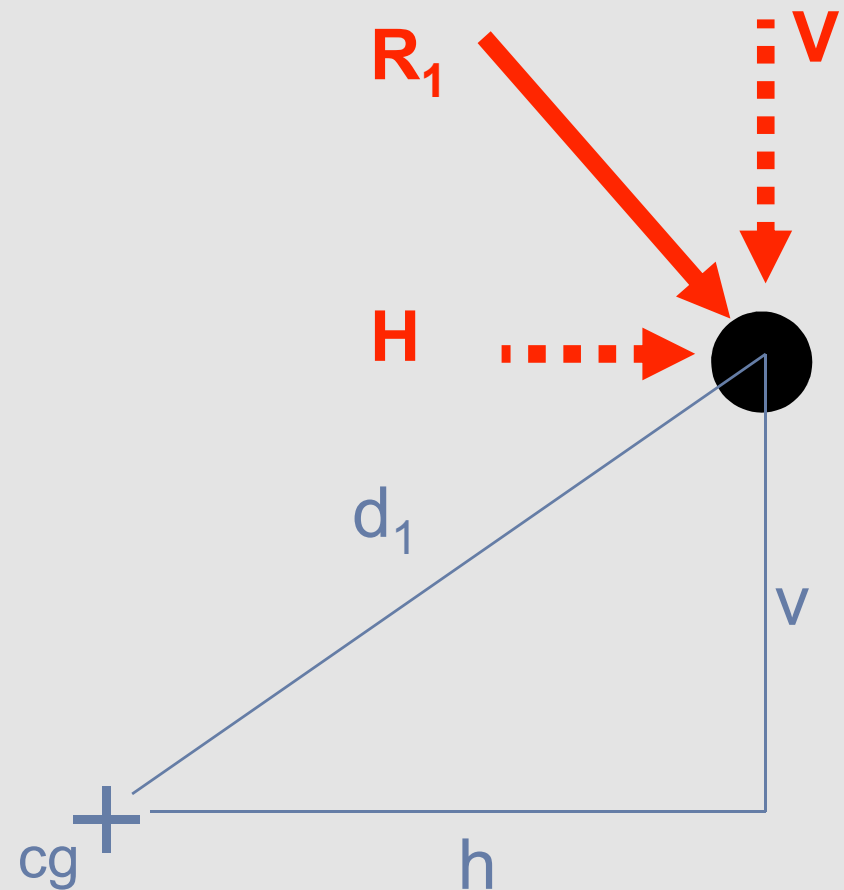
Elastic Method

(Ecc. in Plane of Faying Surface)

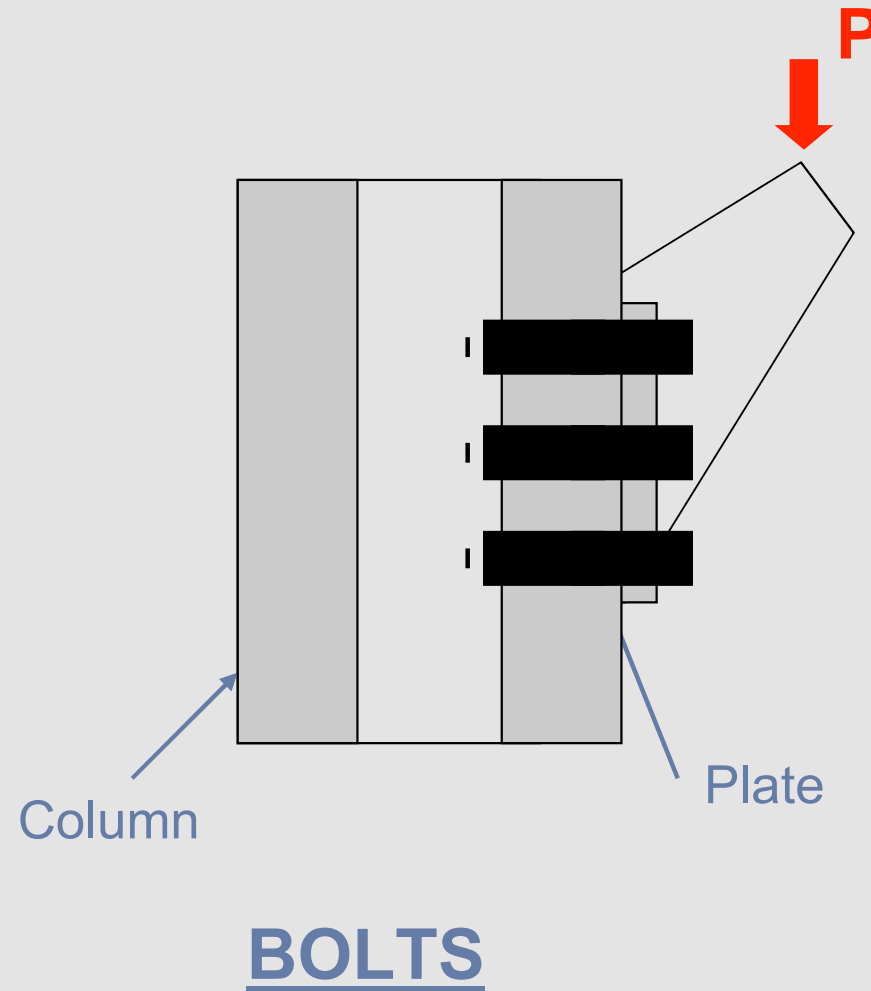
$$H_{bolt} = \frac{P_h}{n} + \frac{Mv}{\sum d^2}$$

$$V_{bolt} = \frac{P_v}{n} + \frac{Mh}{\sum d^2}$$

$$R_{bolt} = \sqrt{H_{bolt}^2 + V_{bolt}^2}$$

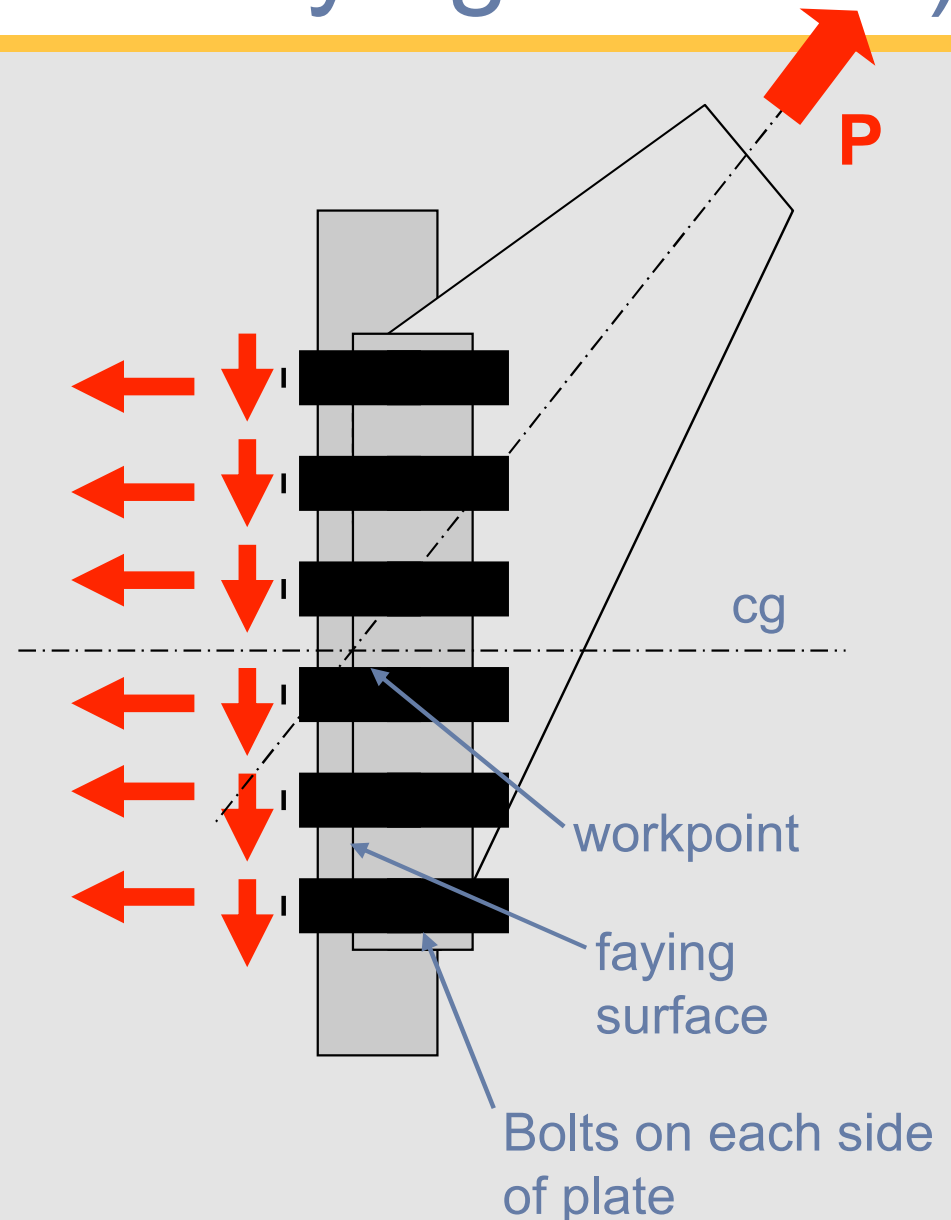


Combined Shear & Tension (Ecc. Normal to Plane of Faying Surface)



Combined Shear & Tension (Ecc. Normal to Plane of Faying Surface)

- When work point of force is at C.G. of bolt group:
 - Direct tension and shear forces are shared equally by each of the bolts

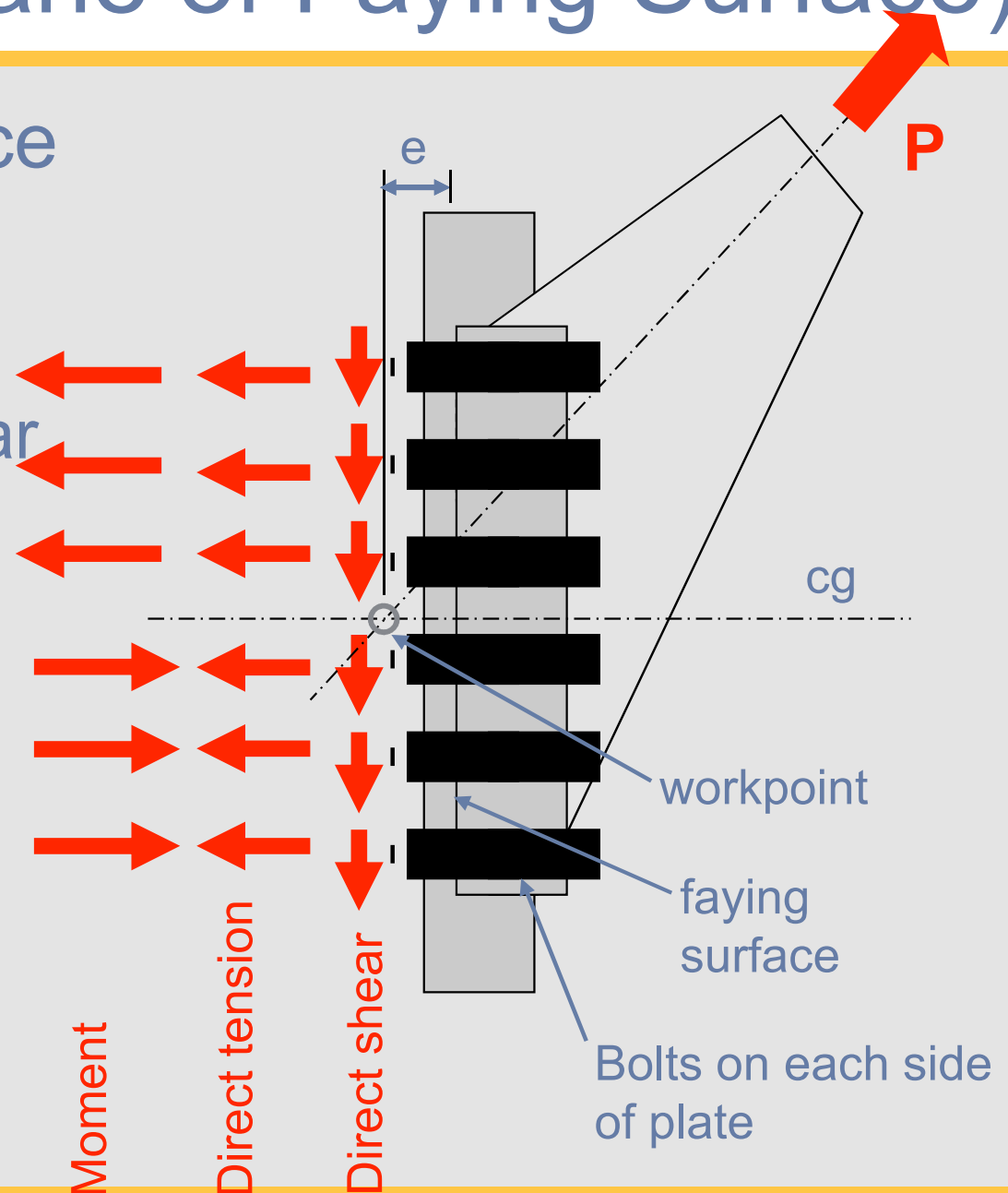


Case II Analysis

(Ecc. Normal to Plane of Faying Surface)

- When work point of force is eccentric normal to the faying surface:

- Direct tension and shear are shared equally between bolts
- Moment due to eccentricity is resisted using a plastic distribution for tension (Case II assumption in AISC Part 7)



Case II Analysis

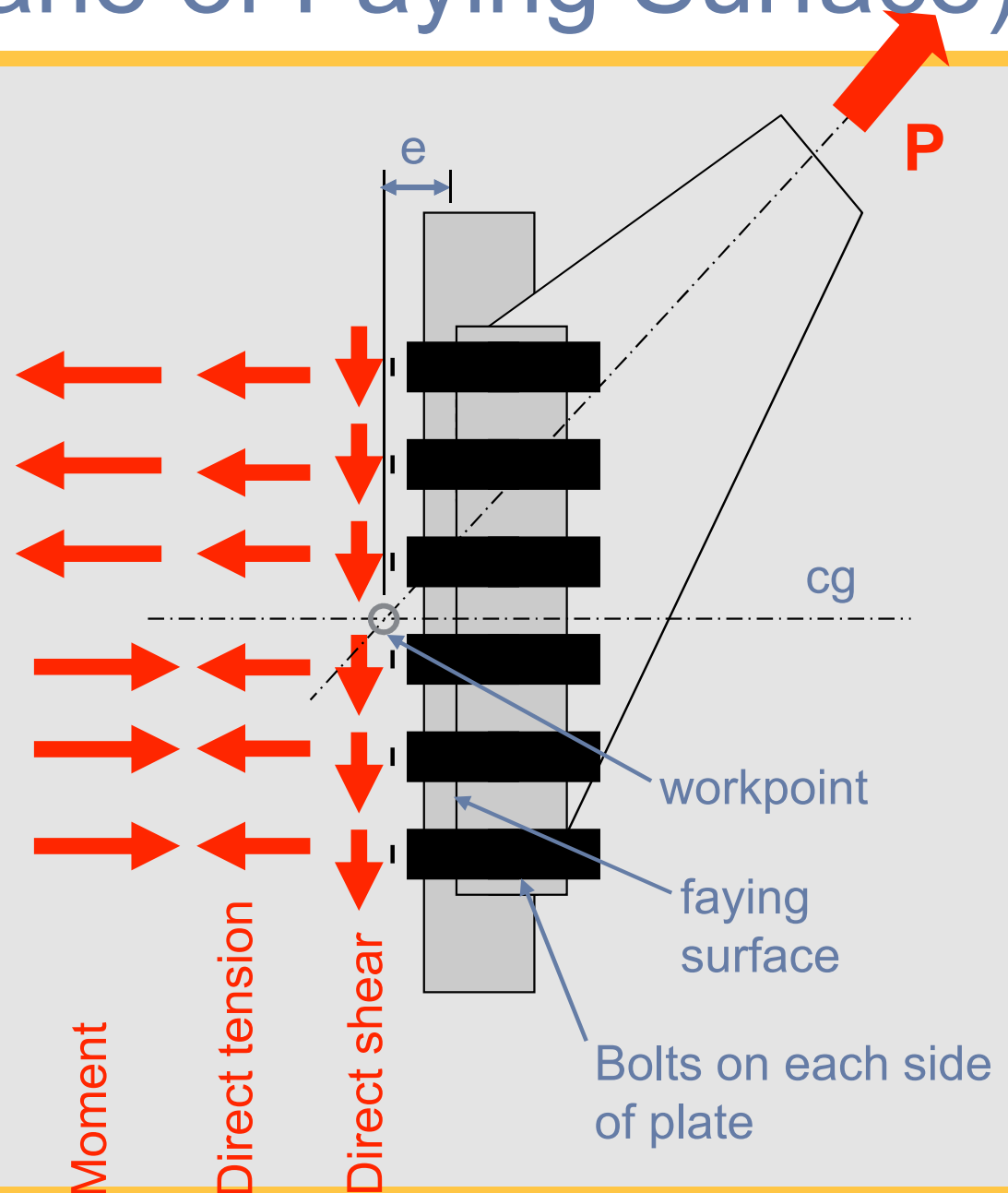
(Ecc. Normal to Plane of Faying Surface)

$$V_{bolt} = \frac{P_v}{n}$$

$$T_{bolt} = \frac{P_h}{n} + \frac{P_v e}{n' d_m}$$

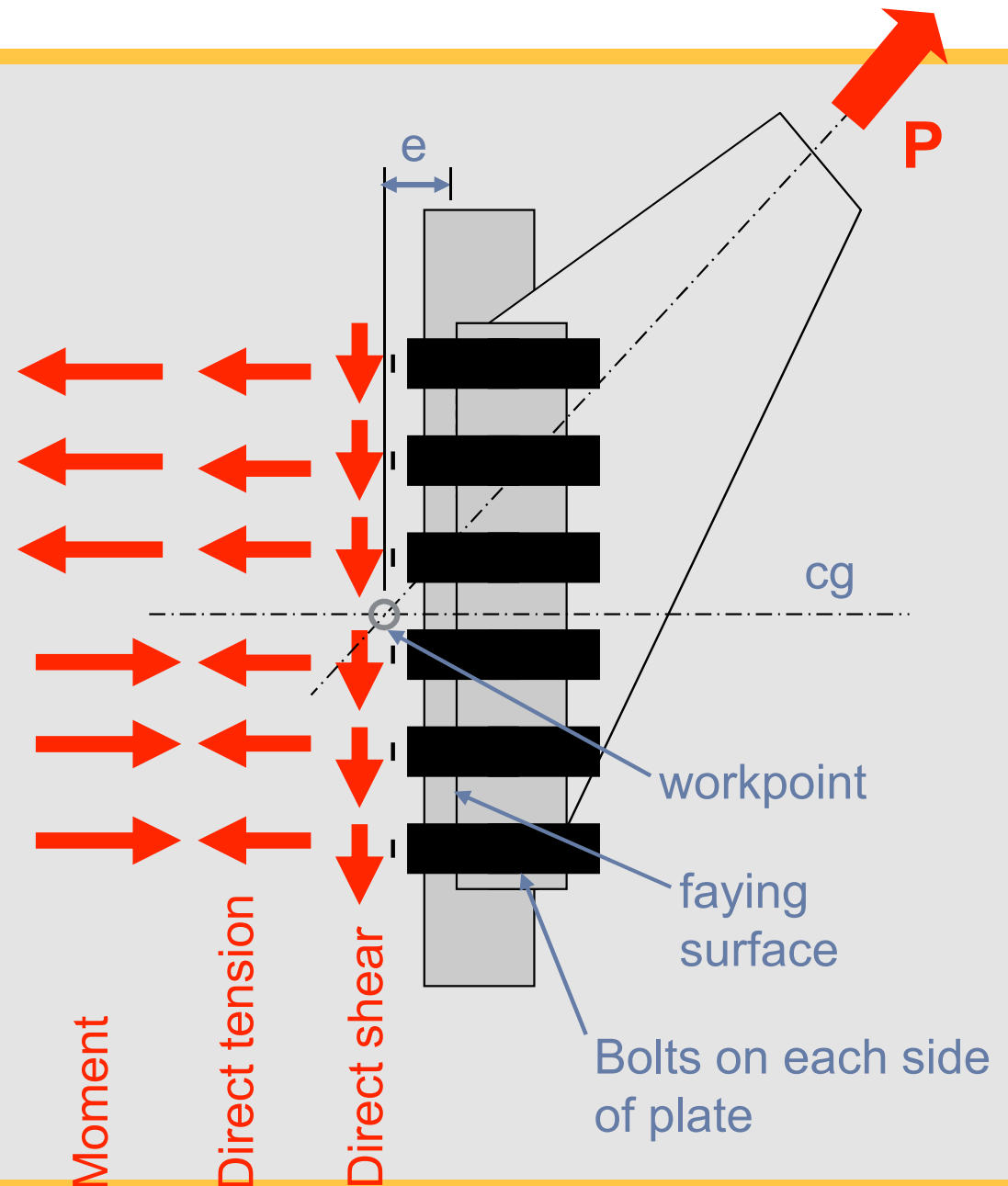
n' = number of bolts
above/below the neutral axis

d_m = moment arm between
resultant tensile force and
resultant compressive force
(for moment component)



Combined Shear & Tension

- Consider bolt shear and tension interaction per AISC
 - J3.7 for bearing
 - J3.9 for S.C.



Eccentric Welded Connections

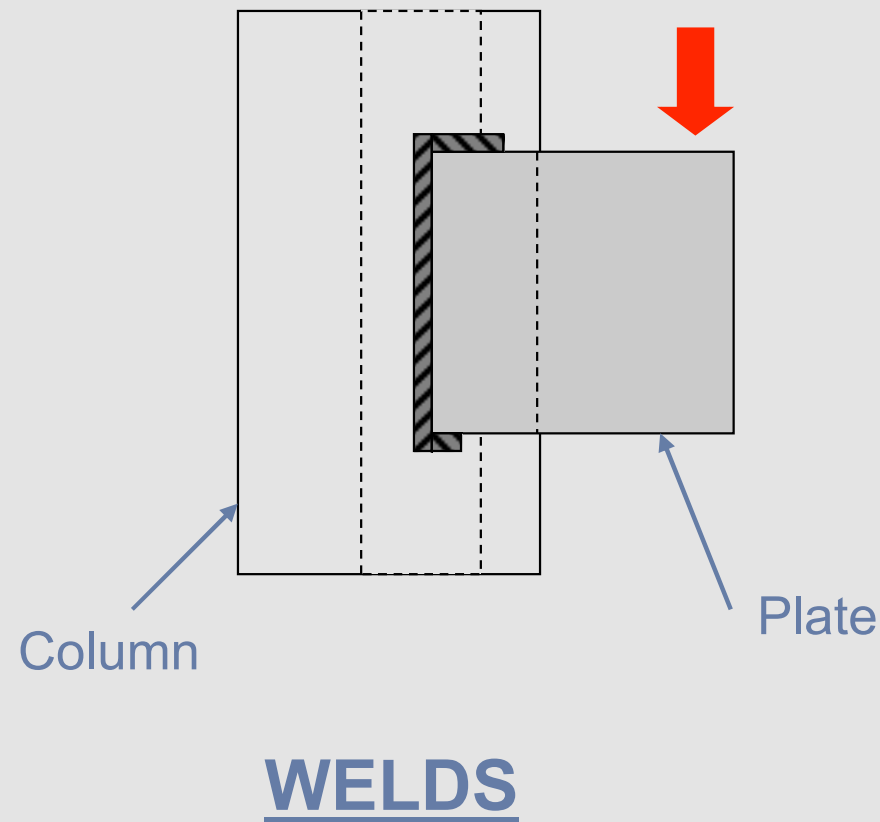
Weld Analysis Methods

- Elastic Method
 - Conservative approach
 - Historically used & most commonly used approach
 - Assumes only deformation in the welds
 - Connected pieces considered rigid
- Instantaneous Center of Rotation Method
 - Considers load-deformation relationship of weld which varies with angle of load from axis of weld (θ)
 - Less conservative but more tedious to apply
 - Tables in manual are useful (but only if weld pattern is a match)

We will focus on the Elastic Method only

Combined Shear

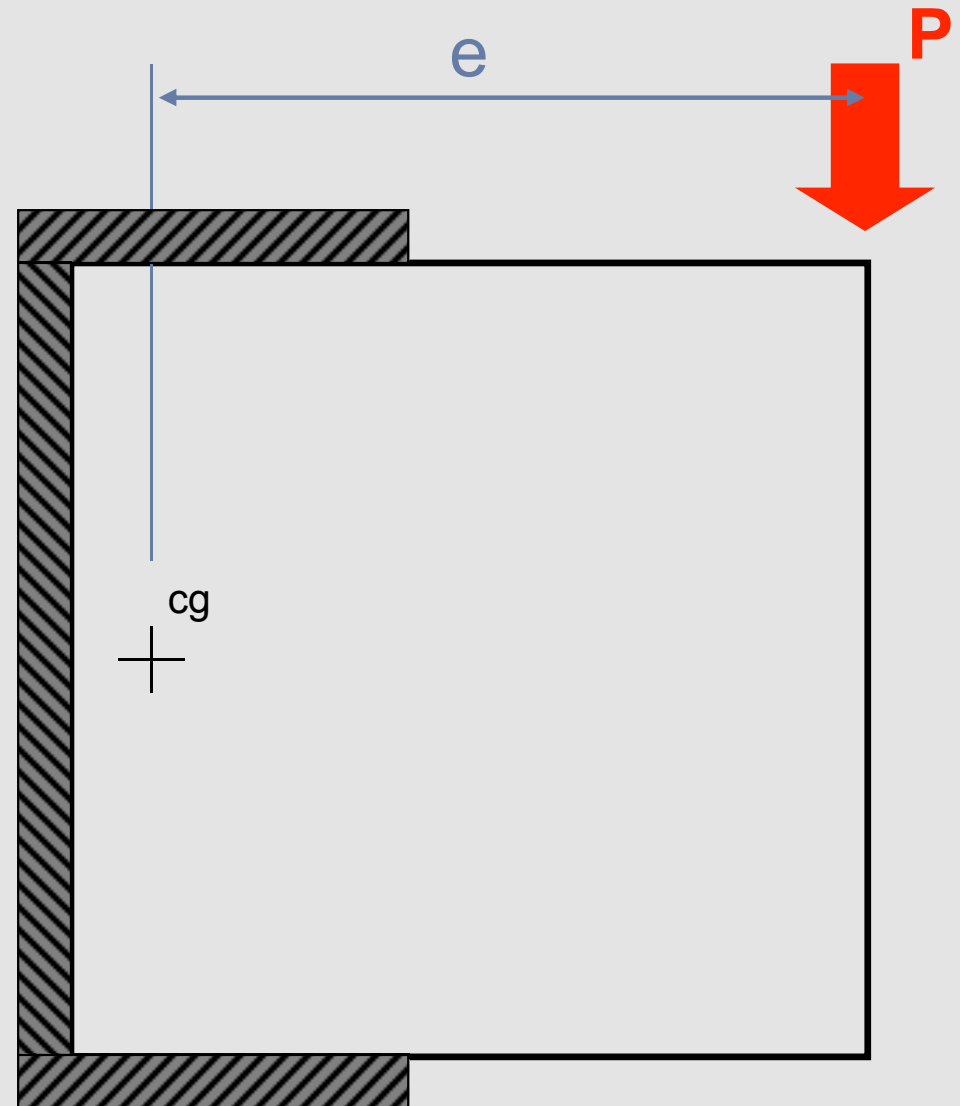
(Ecc. in Plane of Faying Surface)



Elastic Method

(Ecc. in Plane of Faying Surface)

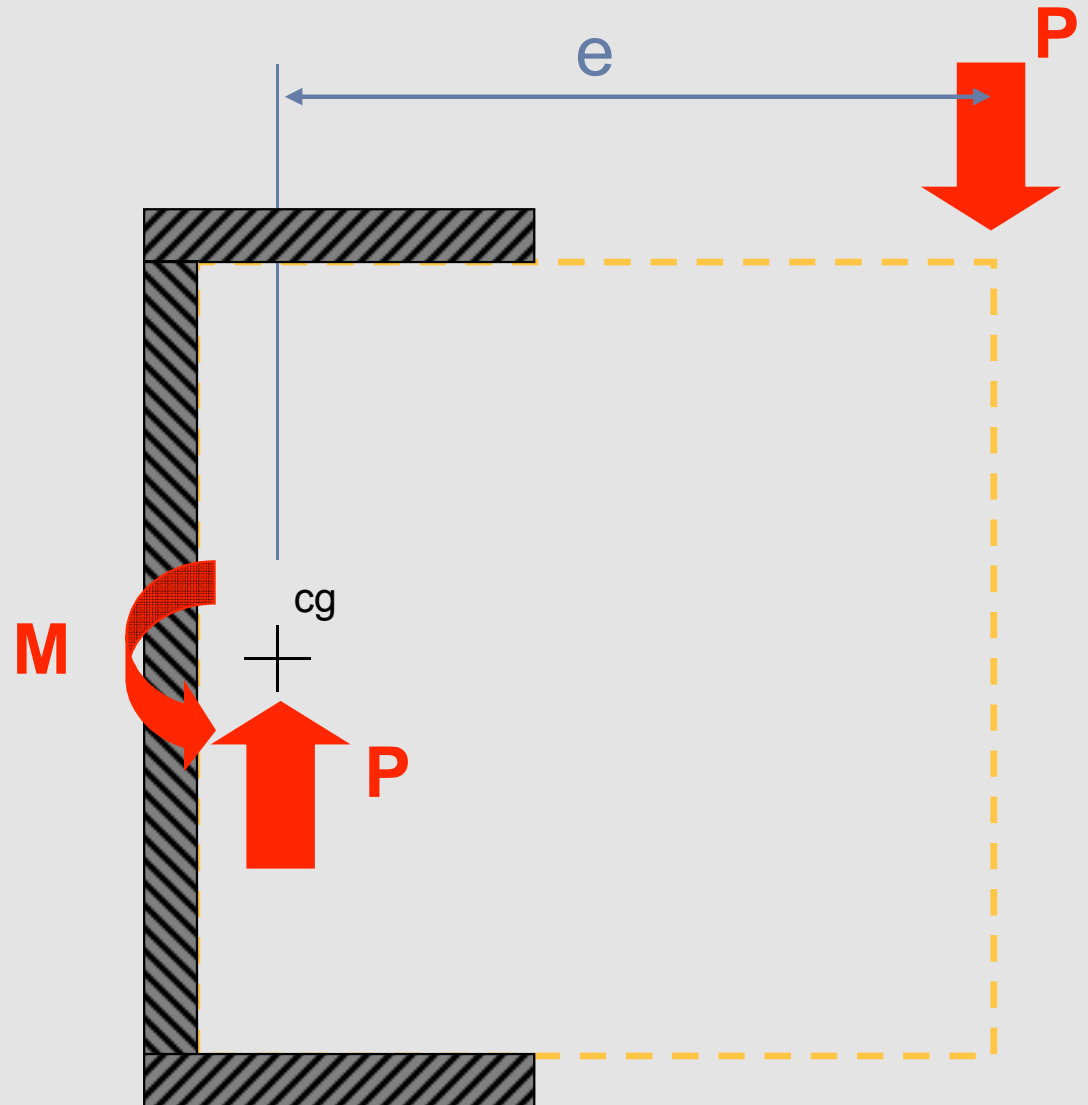
- Force is applied offset from the C.G. of the weld



Elastic Method

(Ecc. in Plane of Faying Surface)

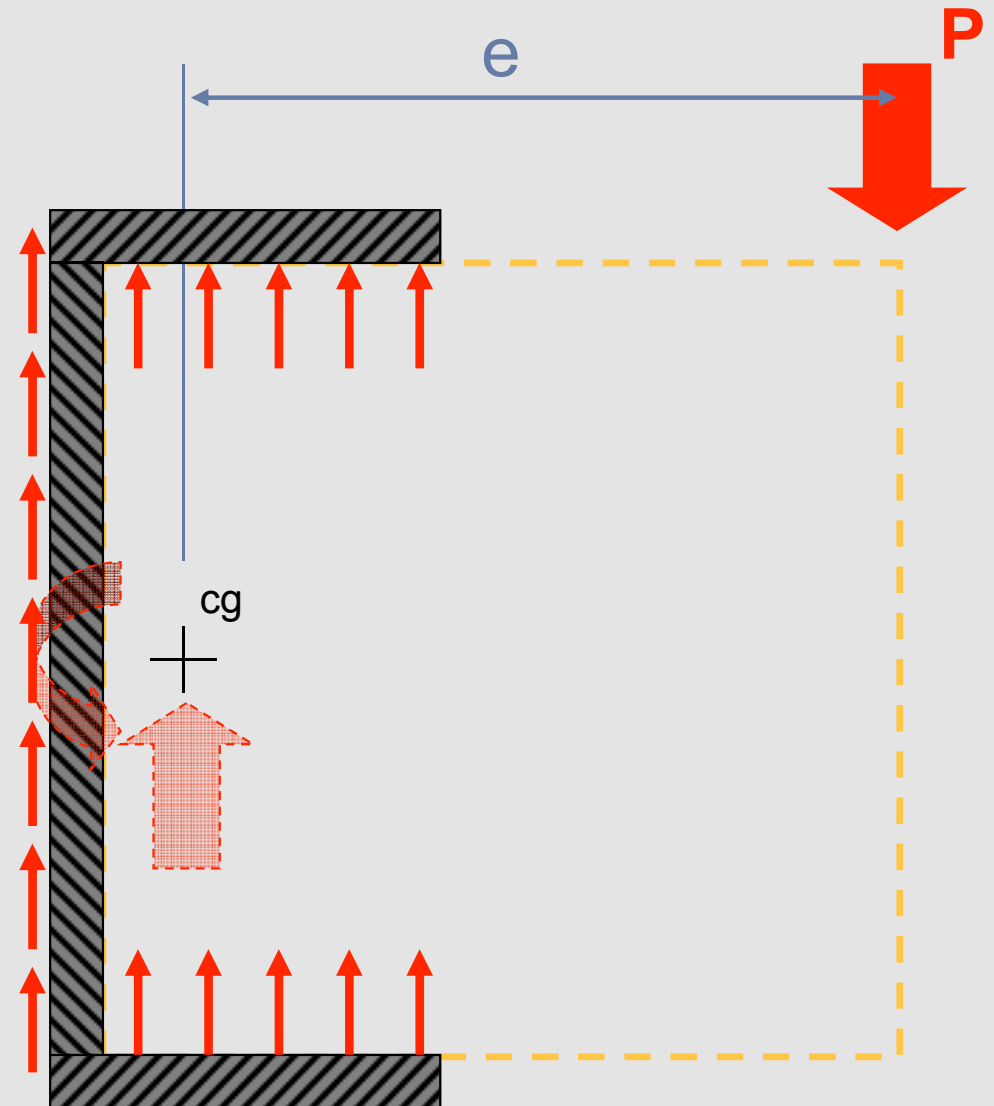
- Equivalent force-couple occurs at C.G. of weld



Elastic Method

(Ecc. in Plane of Faying Surface)

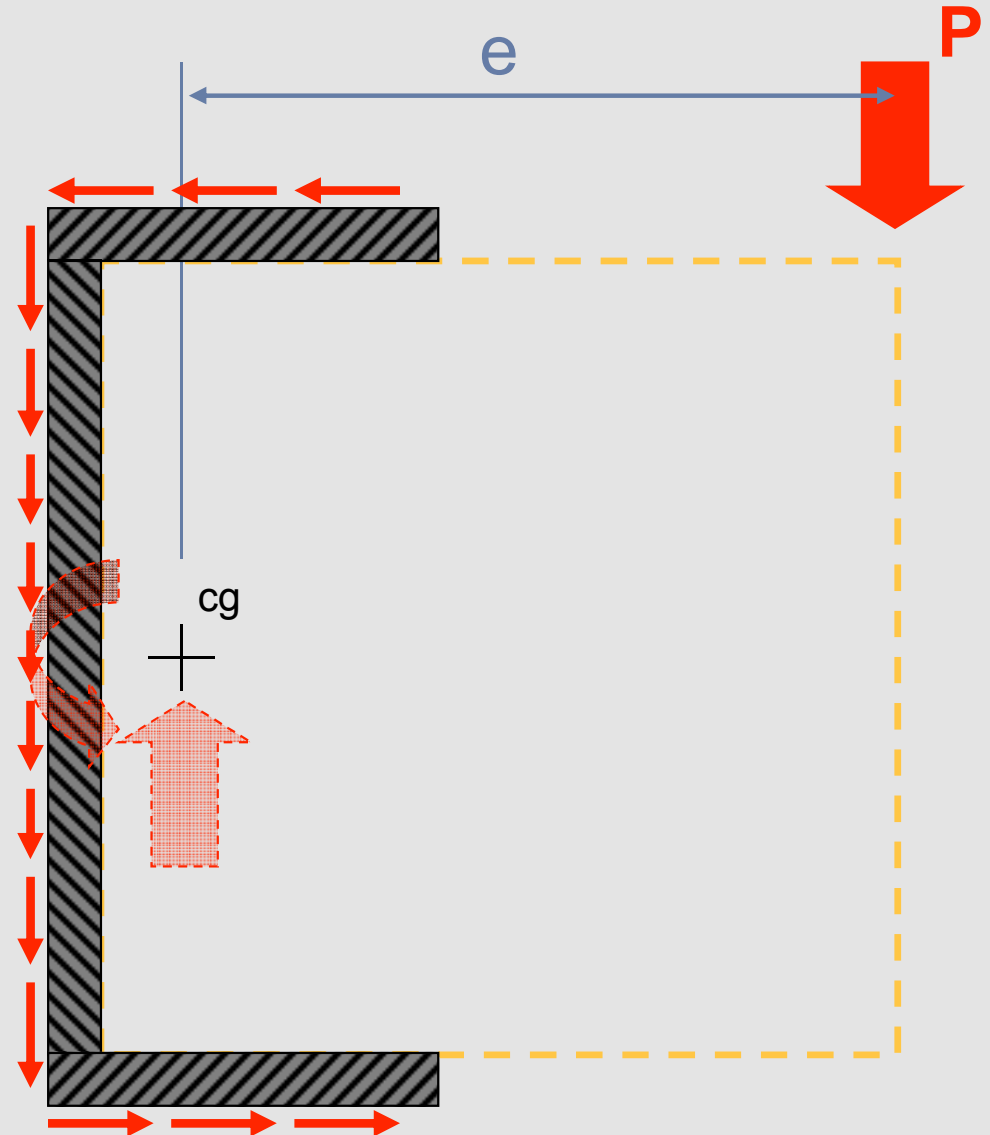
- Direct shear is distributed evenly along the length of the weld



Elastic Method

(Ecc. in Plane of Faying Surface)

- Moment resisted in proportion to the of distance from the C.G. of the weld (elastic distribution)



Elastic Method

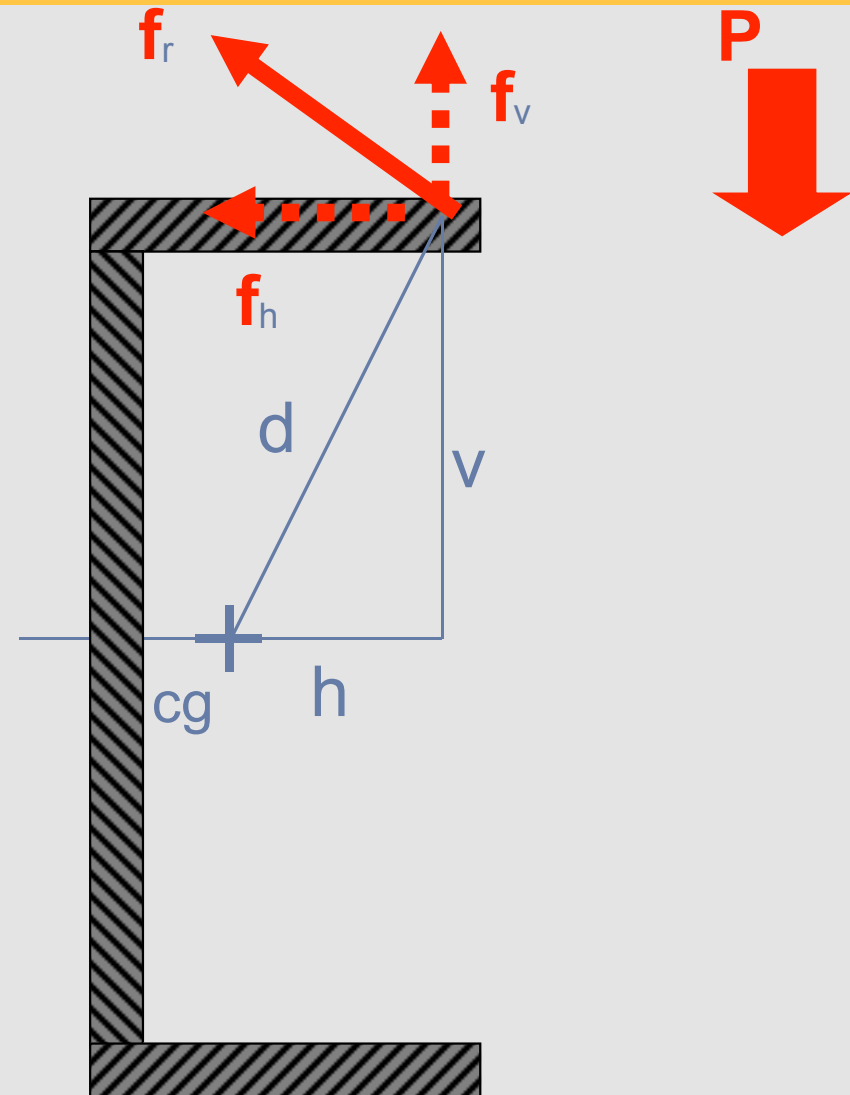
(Ecc. in Plane of Faying Surface)

$$f_h = \frac{P_h}{L_w} + \frac{Mv}{I_p} \quad [\text{kip/in}]$$

$$f_v = \frac{P_v}{L_w} + \frac{Mh}{I_p} \quad [\text{kip/in}]$$

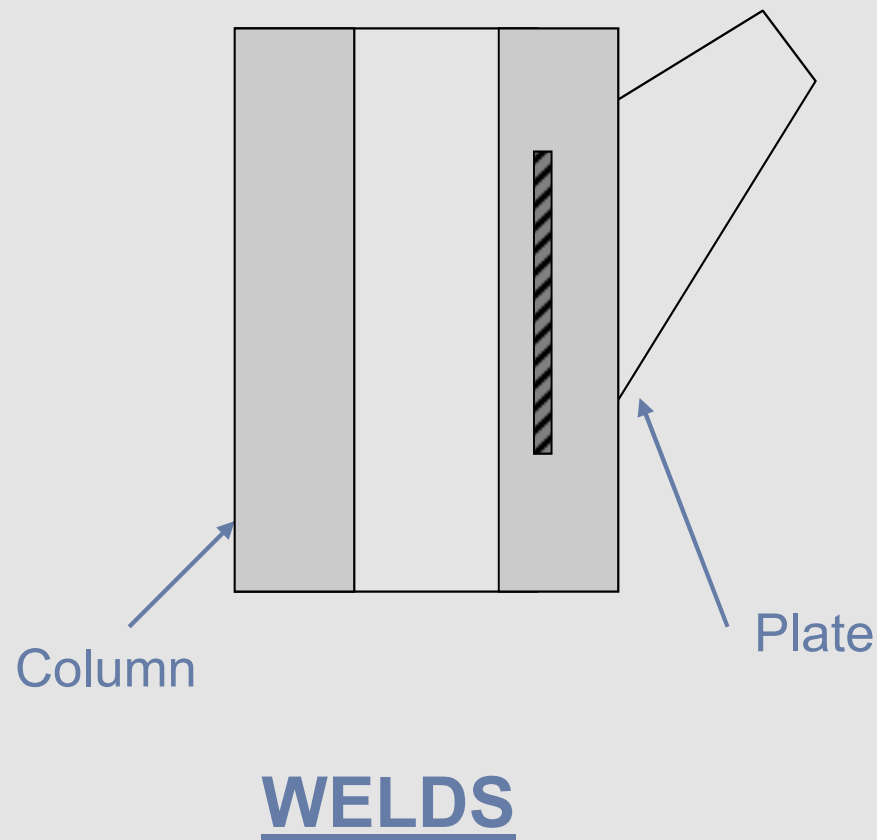
$$f_r = \sqrt{f_v^2 + f_h^2} \quad [\text{kip/in}]$$

$$I_p = I_x + I_y \quad [\text{in}^3]$$



Elastic Method

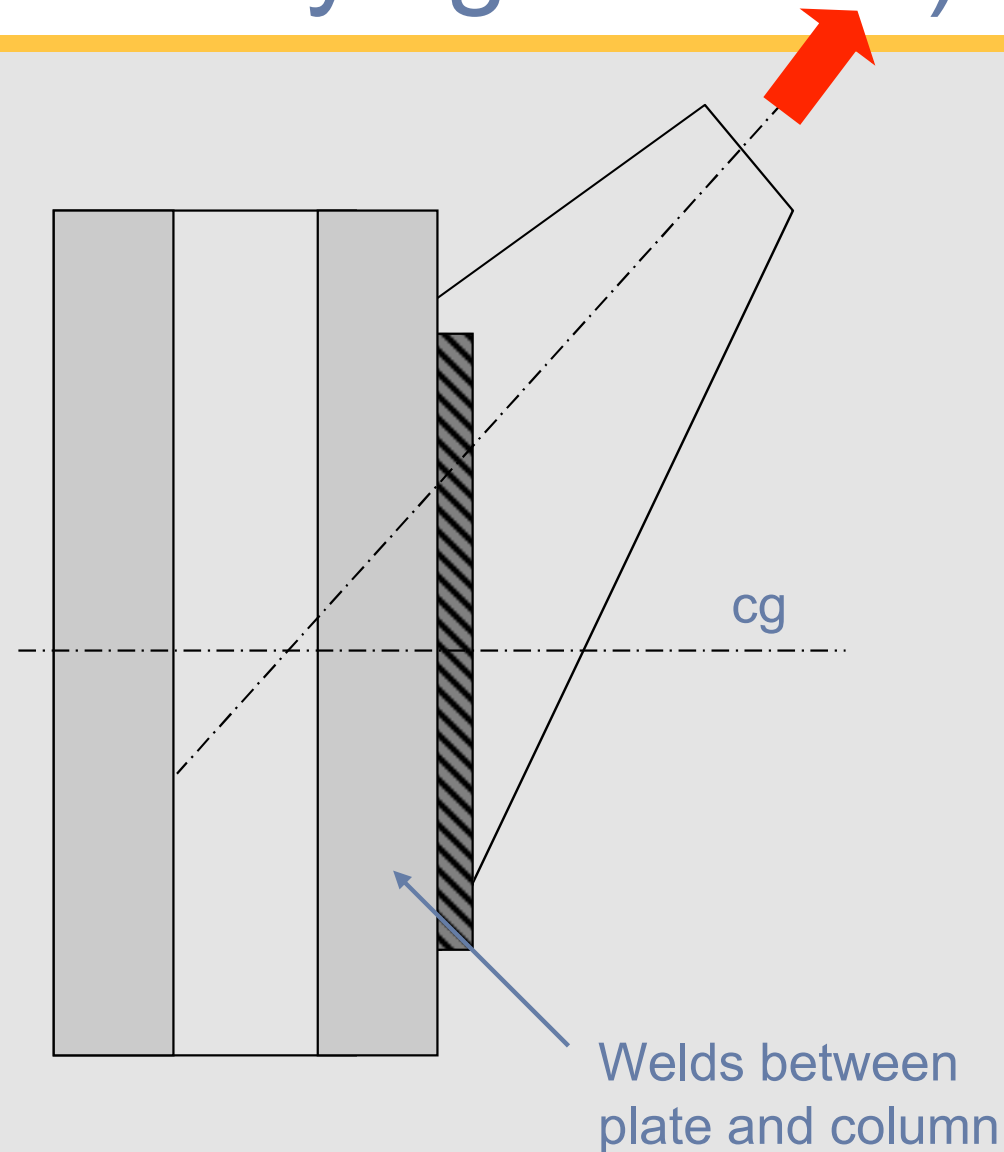
(Ecc. Normal to Plane of Faying Surface)



Elastic Method

(Ecc. Normal to Plane of Faying Surface)

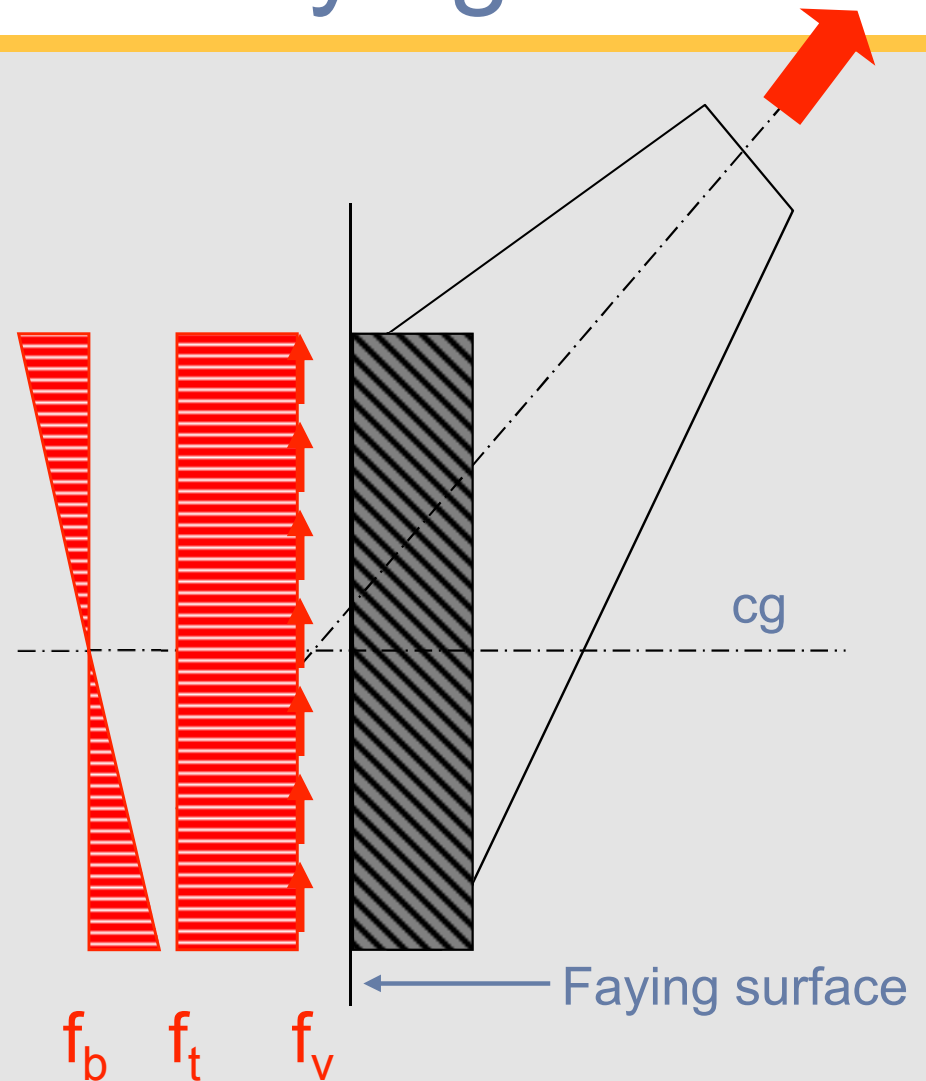
- Shear force is distributed uniformly along the weld length
- Direct tensile force is distributed uniformly along the weld length
- Bending moment is distributed to weld based on elastic distribution (distance from C.G.)
- No tension-shear interaction, as in bolts. Design for resultant shear force.



Elastic Method

(Ecc. Normal to Plane of Faying Surface)

- Shear force is distributed uniformly along the weld length
- Direct tensile force is distributed uniformly along the weld length
- Bending moment is distributed to weld based on elastic distribution (distance from C.G.)

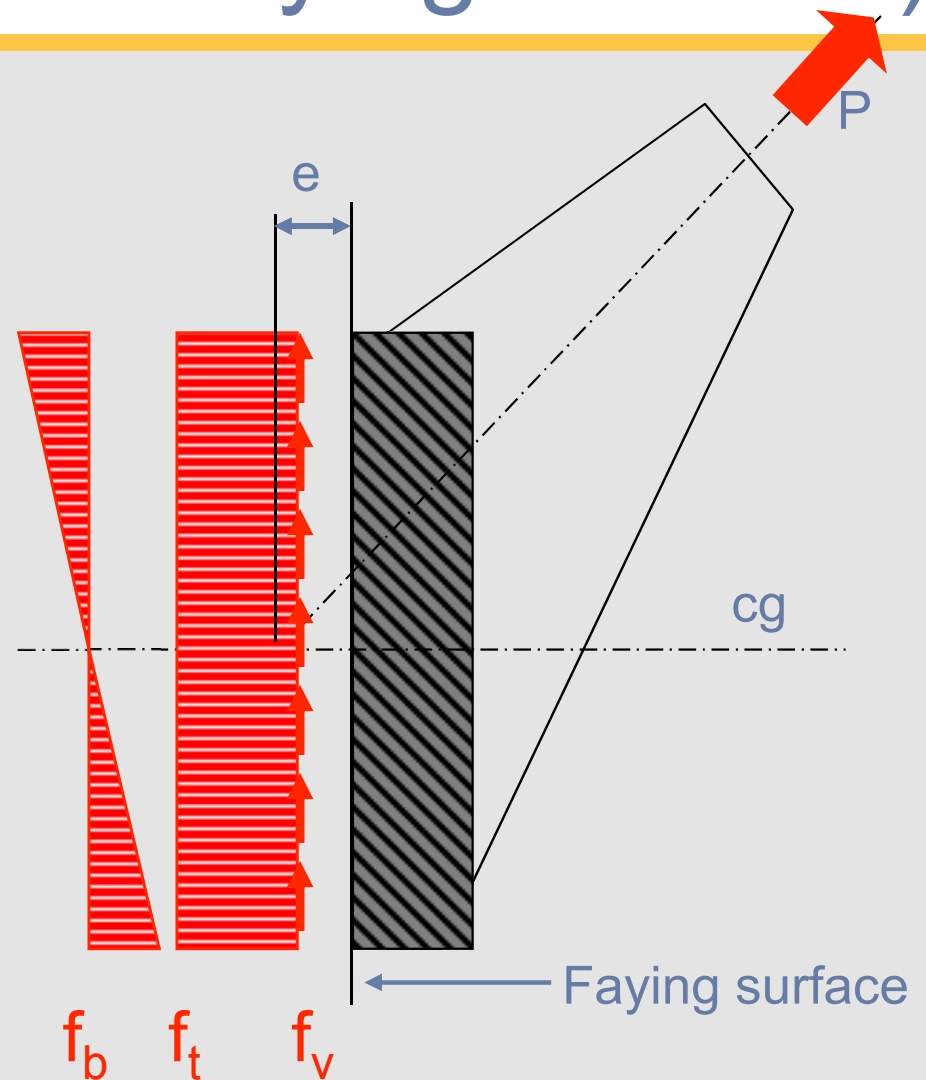


Elastic Method

(Ecc. Norm. to Plane of Faying Surface)

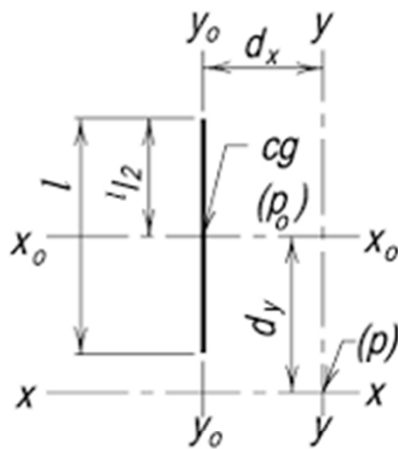
$$f_t = \frac{P_h}{L_w} \quad f_v = \frac{P_v}{L_w}$$
$$f_b = \frac{My}{I} = \frac{P_h e}{I}$$
$$f_r = \sqrt{f_v^2 + (f_t + f_b)^2}$$

Units of f_r are [kip/in]



Section Properties of Weld Groups

- AISC SCM Pg. 8-13

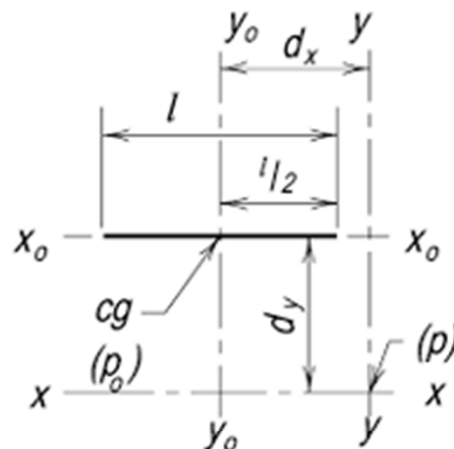


$$I_{x0} = \frac{l^3}{12}$$

$$I_x = \frac{l^3}{12} + l(d_y)^2$$

$$I_{y0} = 0$$

$$I_y = l(d_x)^2$$

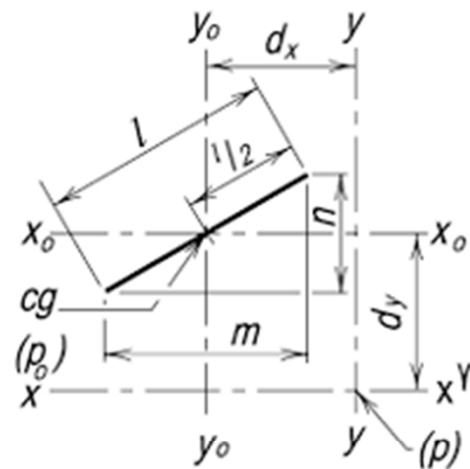


$$I_{x0} = 0$$

$$I_x = l(d_y)^2$$

$$I_{y0} = \frac{l^3}{12}$$

$$I_y = \frac{l^3}{12} + l(d_x)^2$$



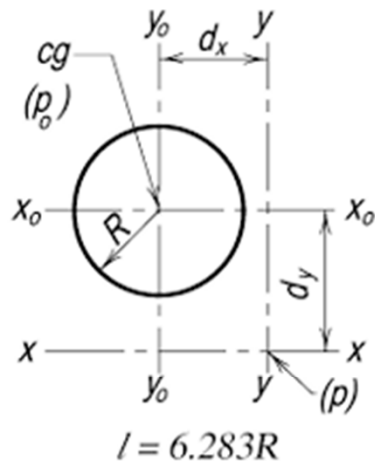
$$I_{x0} = \frac{ln^2}{12}$$

$$I_x = \frac{ln^2}{12} + l(d_y)^2$$

$$I_{y0} = \frac{lm^2}{12}$$

$$I_y = \frac{lm^2}{12} + l(d_x)^2$$

Section Properties of Weld Groups

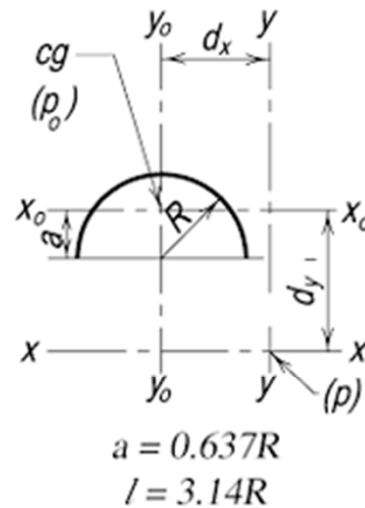


$$I_{x_o} = \pi R^3$$

$$I_x = \pi R^3 + l(d_y)^2$$

$$I_{y_o} = \pi R^3$$

$$I_y = \pi R^3 + l(d_x)^2$$

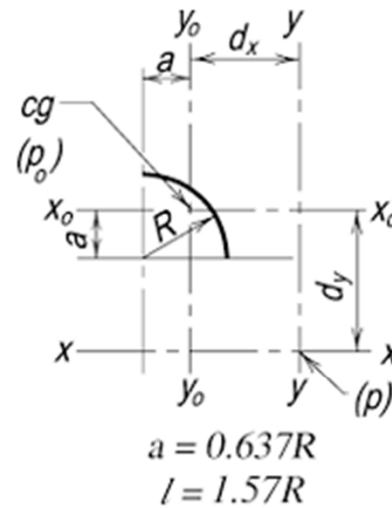


$$I_{y_o} = \frac{\pi}{2} R^3$$

$$I_y = \frac{\pi}{2} R^3 + l(d_x)^2$$

$$I_{x_o} = \left(\frac{\pi}{2} - \frac{4}{\pi} \right) R^3$$

$$I_x = \left(\frac{\pi}{2} - \frac{4}{\pi} \right) R^3 + l(d_y)^2$$



$$I_{x_o} = \left(\frac{\pi}{4} - \frac{2}{\pi} \right) R^3$$

$$I_x = \left(\frac{\pi}{4} - \frac{2}{\pi} \right) R^3 + l(d_y)^2$$

$$I_{y_o} = \left(\frac{\pi}{4} - \frac{2}{\pi} \right) R^3$$

$$I_y = \left(\frac{\pi}{4} - \frac{2}{\pi} \right) R^3 + l(d_x)^2$$

Fig. 8-6. Moments of inertia of various weld segments.

Examples